

NATIONAL ADVISORY COMMITTEE  
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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 327

SOME STUDIES ON THE AERODYNAMIC EFFECT OF THE GAP  
BETWEEN AIRPLANE WINGS AND FUSELAGES

By Shatswell Ober  
Massachusetts Institute of Technology

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Summary

The general result indicated by this study is that if desirable from any viewpoint the gap between wing and fuselage may be closed without detrimental aerodynamic effects, and with a given monoplane there is less drag if the wing is directly on top of the fuselage than if it is parasol.

O b j e c t

The question often arises in planning a cabin airplane whether the wing, if a high-wing monoplane, should be directly on the fuselage or above it, as in the parasol type, or if a biplane, whether the fuselage should extend to the upper wing or leave a gap open. This question will be decided usually from consideration of the structure, vision, or general arrangement, but the effect on the aerodynamic characteristics of the airplane must also be considered.

This note gives the results of a few experiments to study the changes in the aerodynamic characteristics. The experimental

work was done as theses by two students\* in aeronautical engineering at the Massachusetts Institute of Technology. The results must be considered largely qualitative due to the small scale of the models, and the complete omission of propulsive effects.

### M o d e l s

Models of three airplanes were used: (A) a small parasol two-seater (Fig. 1); (B) a familiar biplane type of training airplane (Fig. 2); (C) a special high-wing cantilever cabin monoplane (Fig. 3). Three different arrangements of each model were tested which are indicated on the sketches. Arrangement 1 indicates in each case the unmodified design. Change in model A consisted of two separate methods of totally closing the gaps between parasol wing and fuselage; in model B two enclosed cabins, one extending wholly to the upper wing, the other leaving a very small gap; in model C the wing was first raised above the fuselage, then the gap so formed filled, making again a high-wing monoplane, but with somewhat deeper fuselage.

### P r o c e d u r e

Tests were all made on the N.P.L. balance at a wind speed of 40 m.p.h. Lift and drag were measured for all the arrangements, pitching moment for most, and effective downwash for a

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\*"Investigation of the Air Space between the Fuselage and Upper Wing of an Aeroplane," by Walter B. Griffin, 1927; and "The Effect of Various Modifications in Monoplane Design," by Lucien H. Von Schilling, 1928.

few cases. It must be remembered that effective downwash includes tail-plane efficiency as influenced by the fuselage as well as the actual change in direction of air flow due the wing. Results are expressed as coefficients:

$$C_L = \text{lift coefficient} = \frac{\text{lift}}{qS}$$

$$C_D = \text{drag coefficient} = \frac{\text{drag}}{qS}$$

$$C_M = \text{moment coefficient} = \frac{M_{c.g.}}{cqS}$$

$$q = \text{dynamic pressure}$$

$$S = \text{wing area}$$

$$c = \text{wing chord}$$

### Results and Discussion

The effect on lift is found by comparing the angle of zero lift, the slope of the lift curve, and maximum lift.

	Model A		
Arrangement	1	2	3
Angle of zero lift	-5.3°	-3.7°	-6.2°
Slope of lift curve	0.856	0.880	0.872
Maximum $C_L$	1.604	(lower)	1.525

Model B			
Arrangement	1	2	3
Angle of zero lift	$-3.6^{\circ}$	$-3.3^{\circ}$	$-4.9^{\circ}$
Slope of lift curve	0.715	0.731	0.742
Maximum $C_L$	1.173	1.173	

Model C			
Arrangement	1	2	3
Angle of zero lift	$-3.4^{\circ}$	$-3.4^{\circ}$	$-2.9^{\circ}$
Slope of $C_L$ curve	0.970	0.970	0.970
Maximum $C_L$	1.564	1.525	1.564

The angle of zero lift may be changed up to about  $1^{\circ}$  by a reasonable fair closing of the gap, or there may be practically no change. The slope is unaffected, indicating that the effective aspect ratio is little influenced. The maximum may be reduced slightly, but probably not over 3 per cent.

"Polar" curves of  $C_L$  vs.  $C_D$  are plotted for each case except the third arrangement of Model B (Figs. 4, 5, and 6). Minimum drag coefficients are given below:

Model A			
Arrangement	1	2	3
$C_D$ min.	0.0786	0.0739	0.0758

## Model B

Arrangement	1	2	3
$C_D$ min.	0.0535	0.0535	0.0563

## Model C

Arrangement	1	2	3
$C_D$ min.	0.0582	0.0633	0.0622

The poorest case of closing the gap - Model B, 1 and 2 - gives the same  $C_D$  even with the greater fuselage cross section. The mean reduction on the three models is about 3 per cent (approximately the same as the reduction in  $C_L$  maximum). The increase drag when the cabin of the biplane does not reach the upper wing is very marked, some 6 per cent. Also with the same fuselage the parasol Model C-2 has appreciably higher drag than the high wing, C-1 (9 per cent).

For Model C high speeds, rates of climb and stalling speeds have been calculated, using the same method and total weight throughout.

## Model C

Arrangement	1	2	3
High speed m.p.h.	105	101	101
Rate of climb ft. per sec.	475	440	440
Stalling speed m.p.h.	53	53	53

The advantage of the high wing "1" over the parasol "2" is evident. The second high wing "3" has a much deeper cabin.

Pitching moment coefficients are plotted vs.  $C_L$  (Figs. 7, 8, 9). When the gap is closed without displacing the wing in respect to the tail, the statical longitudinal stability without slipstream effect is almost unaffected. The angle or speed of trim is changed and rather inconsistently. On Model A, the  $C_L$  at equilibrium is reduced from .546 to .208; on Model B, it is increased from .660 to .840; while on Model C, it is unchanged. The particular condition and method of fairing have great influence on the trimming speed. On Model C, the change from high-wing to parasol monoplane changed the character of moment curve, so that at cruising speeds the stability was increased, while at high speeds it was reduced.

Effective downwash (Reference 1) is plotted for models A and B only, and only arrangements 1 and 2 of each (Figs. 10 and 11). The downwash is, at all lifts, increased when the space between the fuselage and wing on either model was closed. The amount is variable, but at the ordinary flying range is slightly over half a degree. The effect of the change in downwash alone on each model would be to give a stalling moment; the moment change on the biplane, Model B, is stalling, but on the monoplane it is diving. This means that in addition there must be a considerable diving moment introduced by the combined effect of changing fuselage and covering part of the under side of the wing.

## C o n c l u s i o n s

This study indicates that except for an unimportant shift in zero lift, the lift curve will probably be only slightly affected by extending the fuselage up to the wing, or by changing from high-wing type to parasol. The drag is little changed by closing the gap between wing and fuselage; if changed it will be decreased. The parasol type appears unfavorable. Downwash will increase perhaps  $\frac{1}{2}^{\circ}$  with resulting increase in stalling moment, unless wing and fuselage moment is changed as well,

It is realized that the conclusions reached must be considered only as indicative rather than absolute, but other information in regard to this effect seems very meager.

Massachusetts Institute of Technology,  
June 6, 1929.

## R e f e r e n c e

1. Warner, Edward P. : "Airplane Design," page 337.



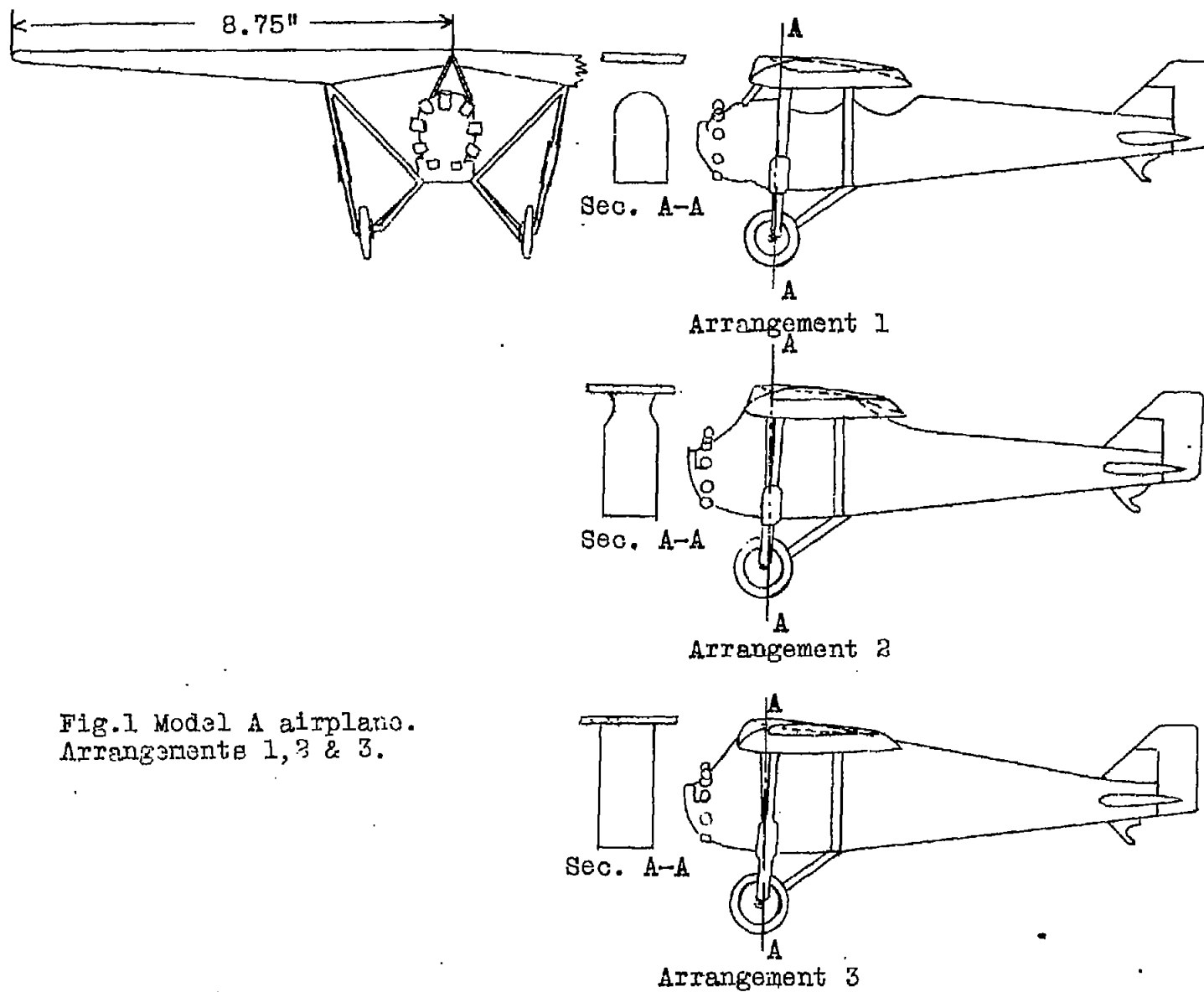


Fig.1 Model A airplane.  
Arrangements 1, 2 & 3.

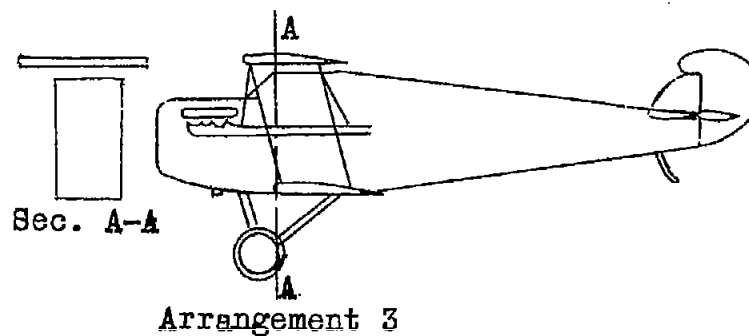
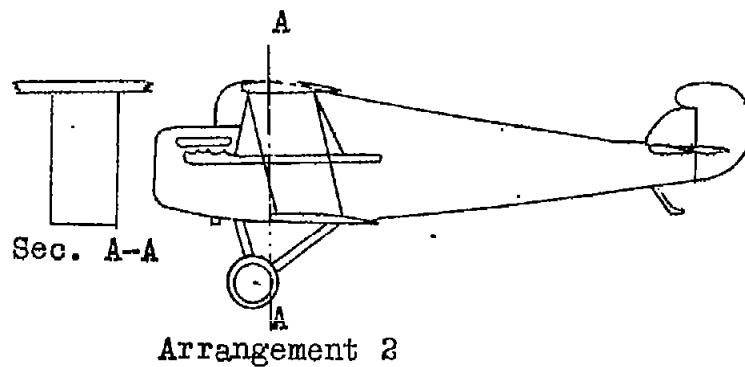
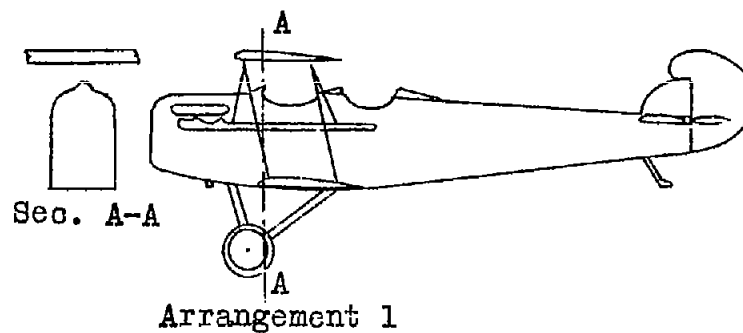
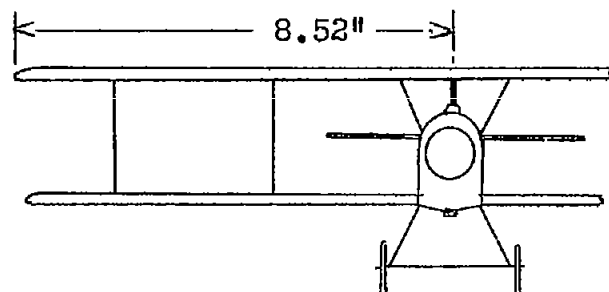


Fig. 2 Model B airplane.  
Arrangements 1, 2 & 3.

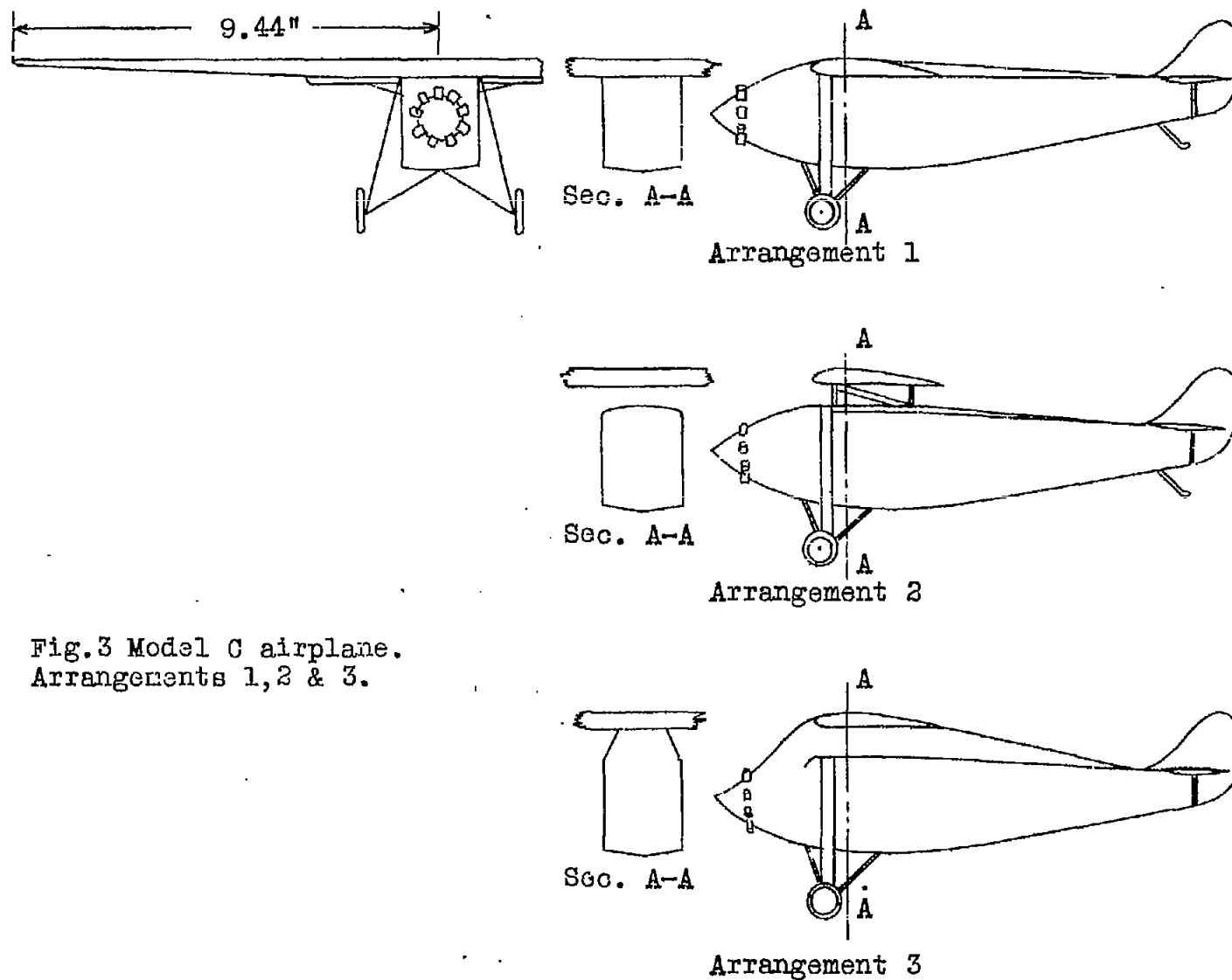


Fig.3 Model C airplane.  
Arrangements 1,2 & 3.

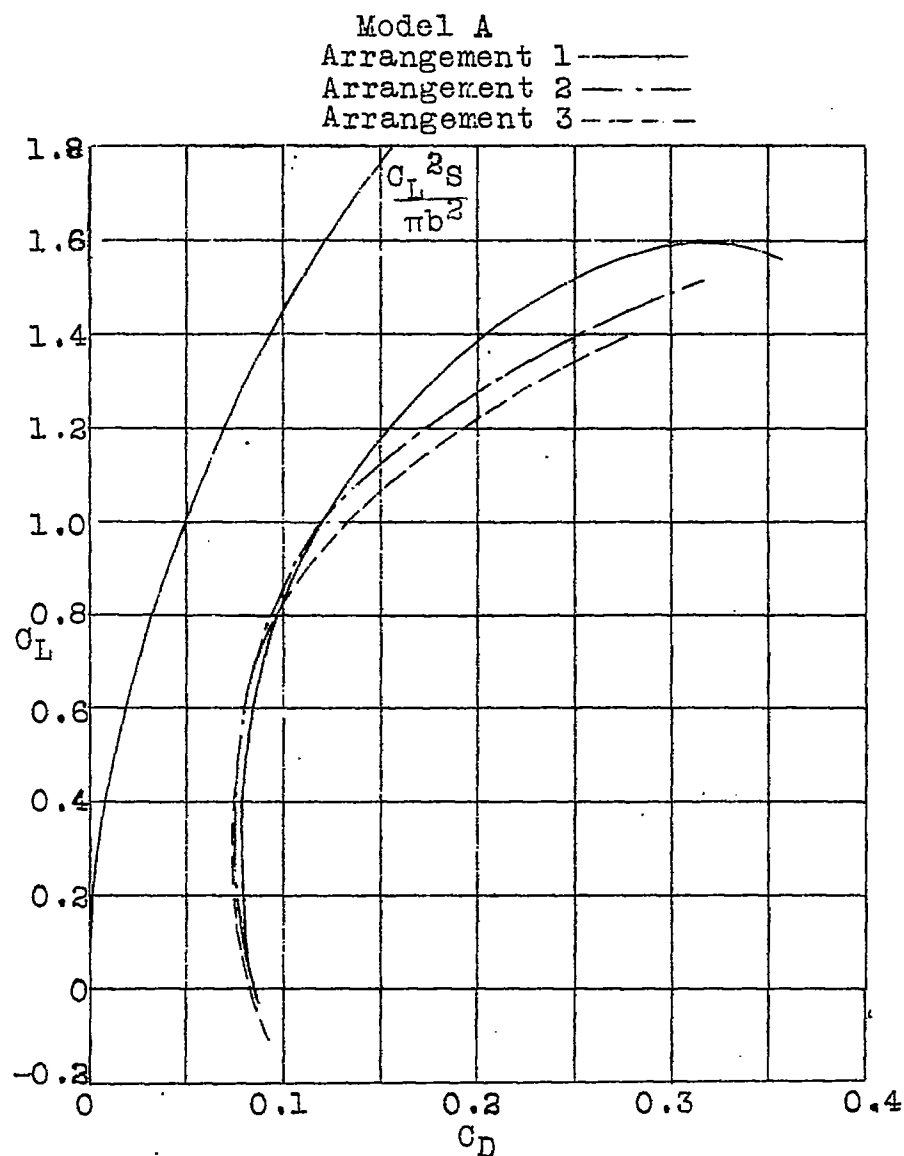


Fig.4 High-wing monoplane.  
Effect of wing location on drag.

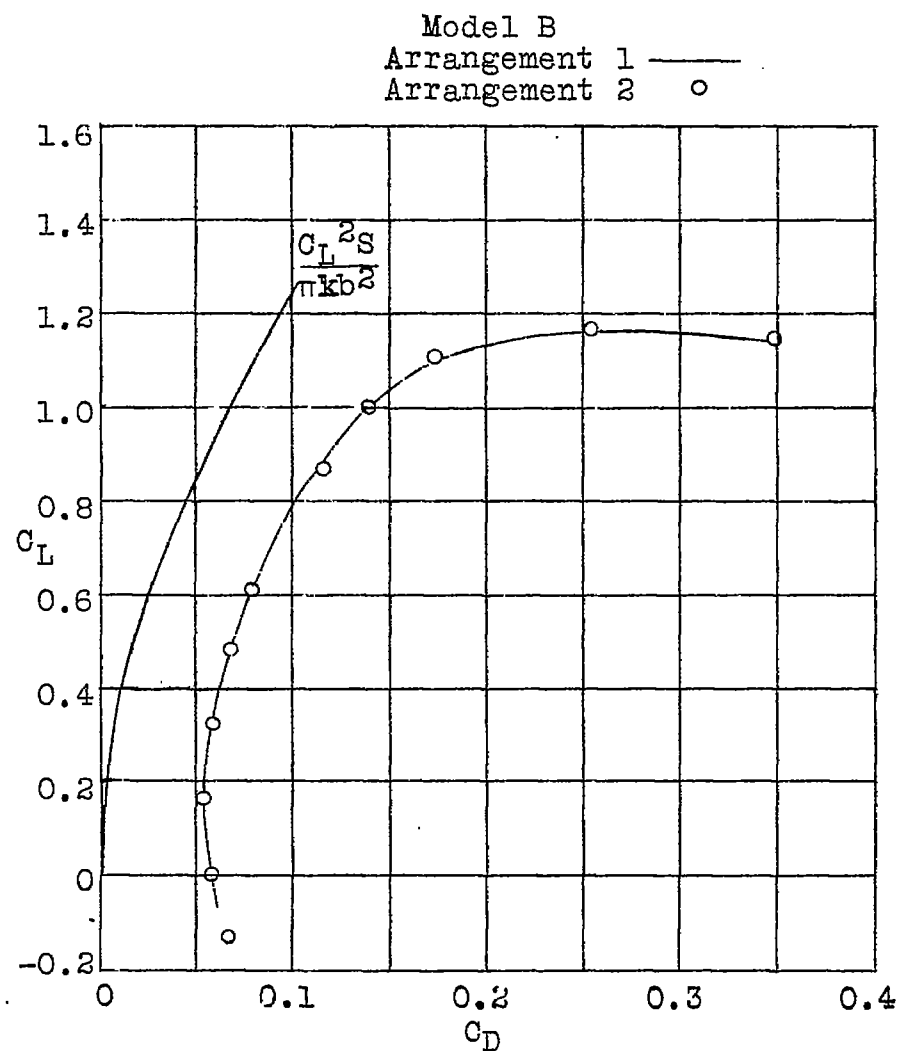


Fig.5 Biplane.  
Effect of upper wing location on drag.

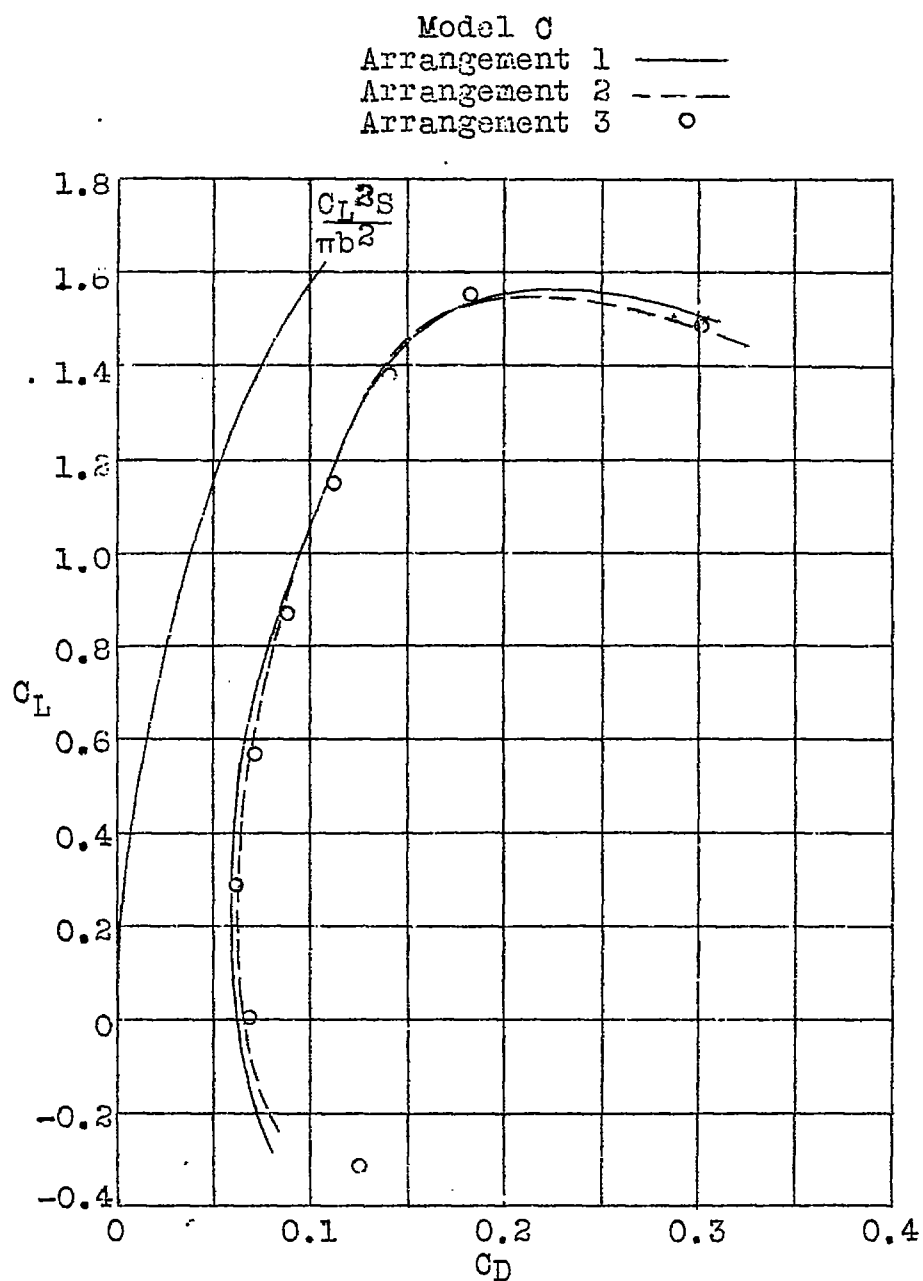


Fig.6 High-wing monoplane.  
Effect of wing location on drag.

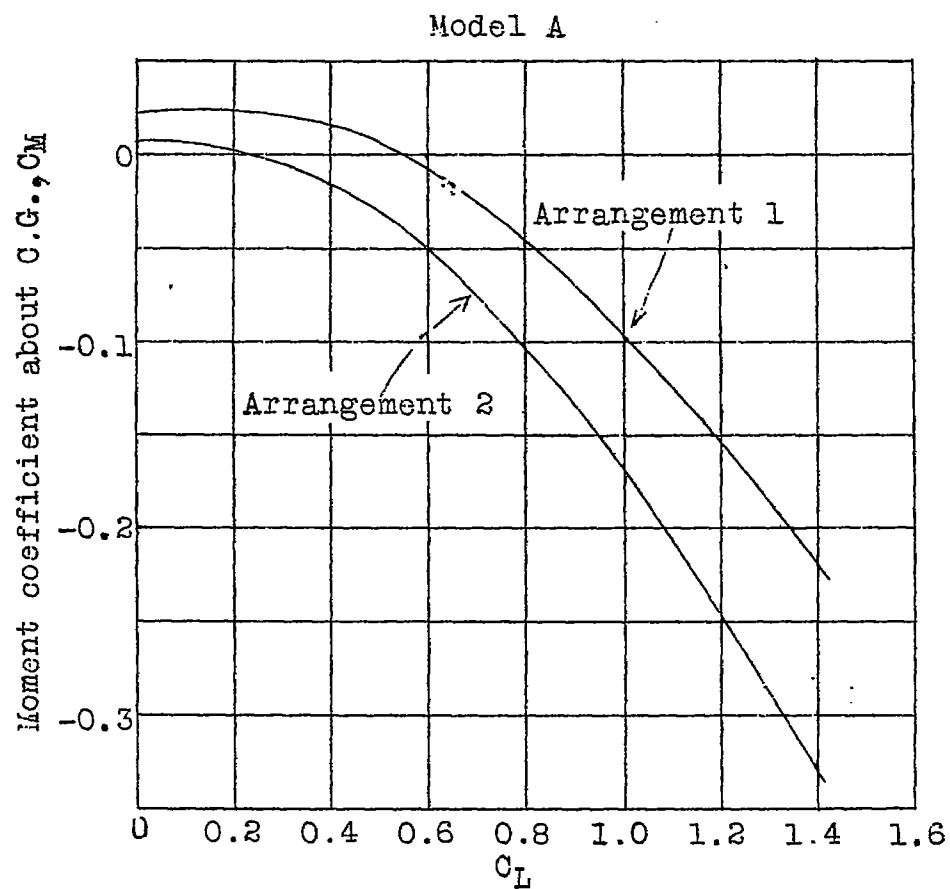


Fig.7 High-wing monoplane.  
Effect of wing location on moment.

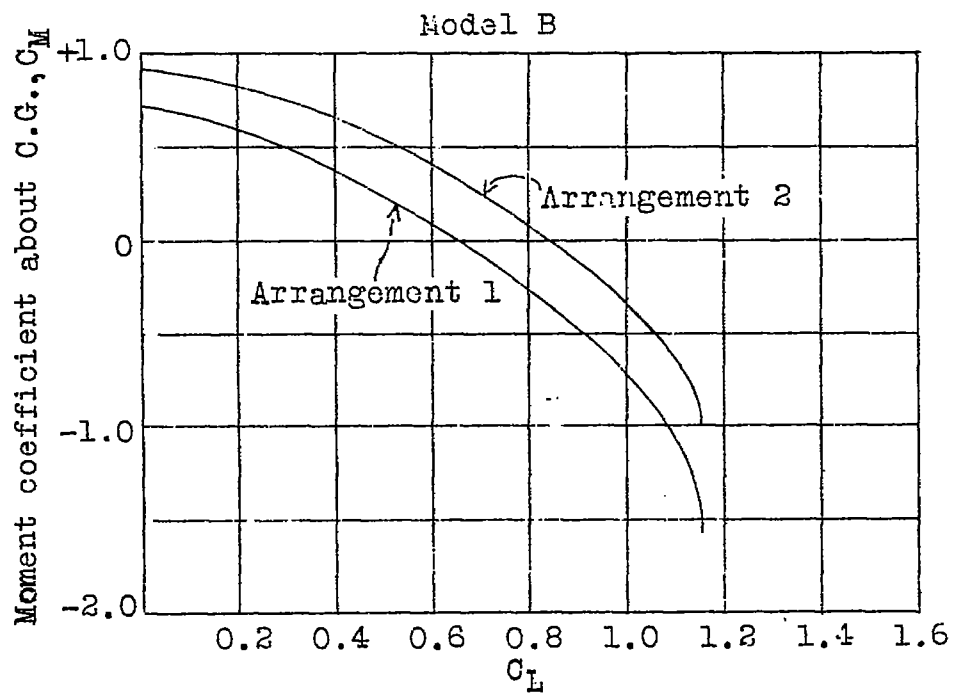


Fig.8 Biplane.  
Effect of upper wing location on moment.



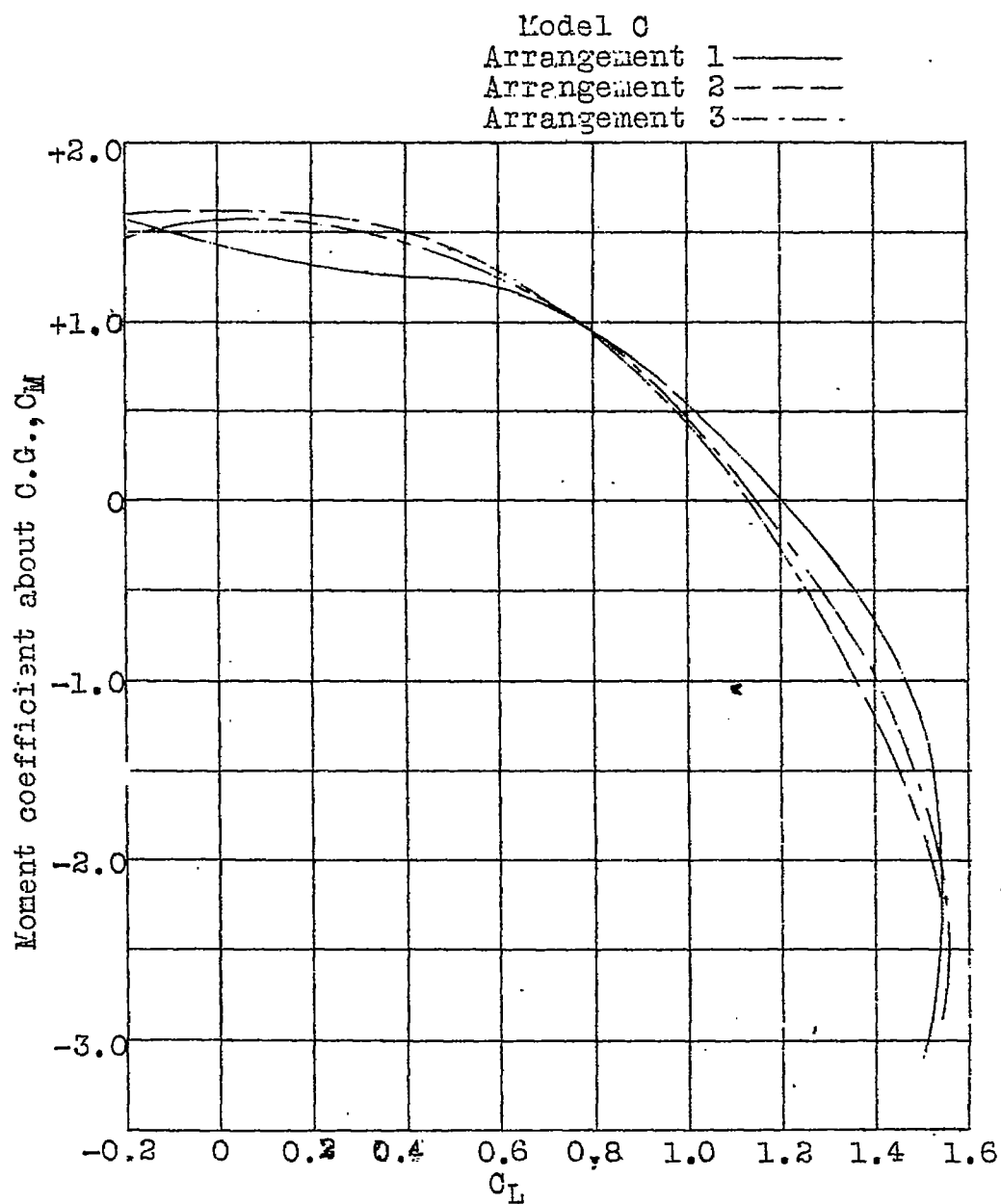


Fig.9 High-wing monoplane.  
Effect of wing location on moment.

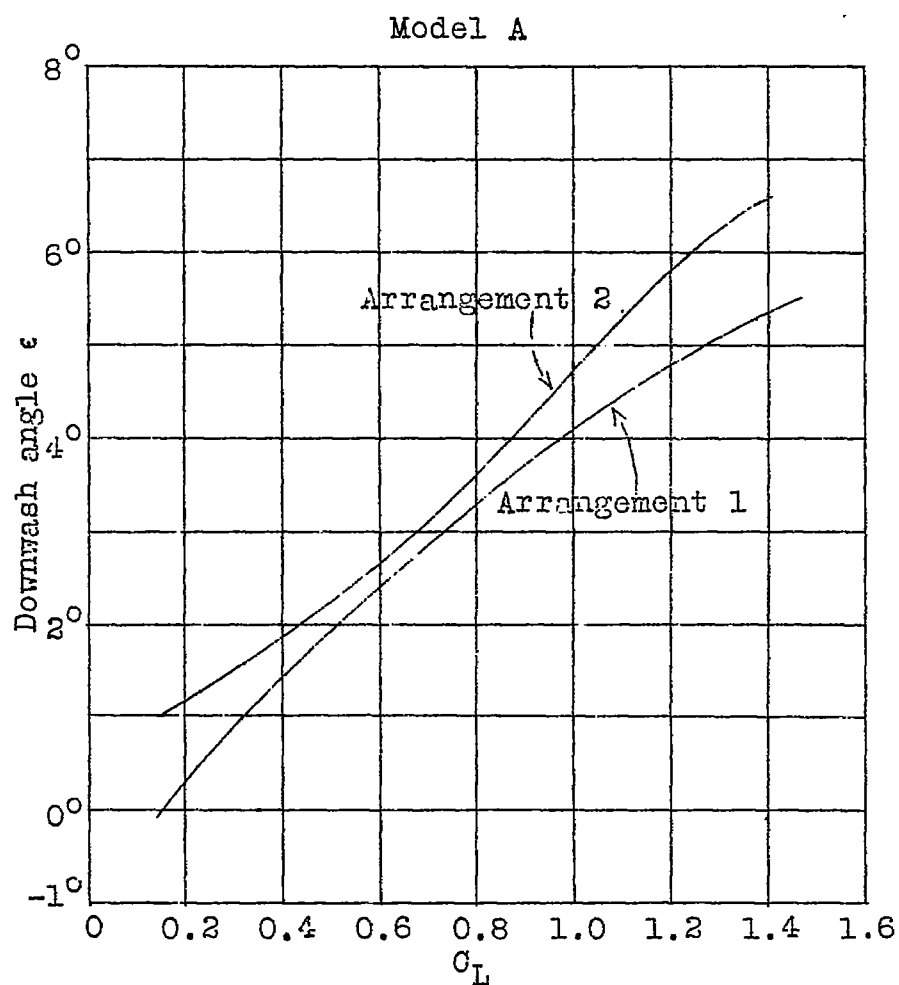


Fig.10 High-wing monoplane.  
Effect of wing location on downwash.

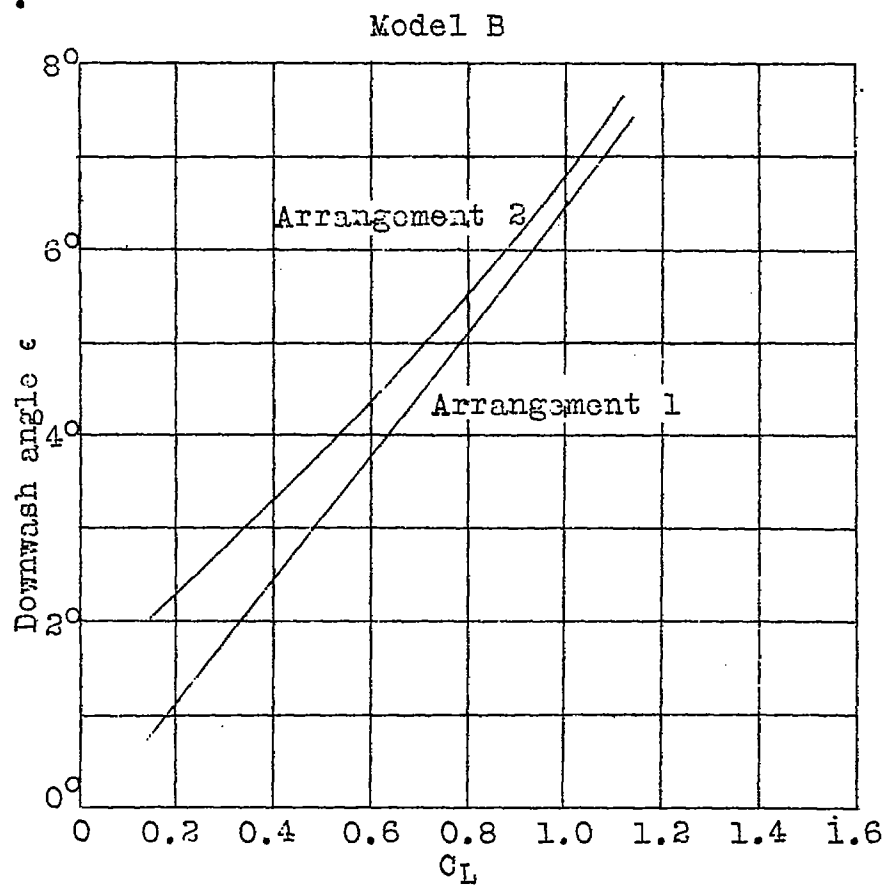


Fig.11 Biplane.  
Effect of upper wing location on downwash.